Chapter 3. Methods

This Chapter describes the common procedures followed, to segment wood images using clustering algorithms. The methods described here are common to all clustering techniques. Boards were scanned using the lumber scanning system at the Brooks Forest Products Research Center, at Virginia Tech [CON97]. The color imaging system is used to obtain a three channel, red, green and blue (r, g, b) image of the board, which was used for further processing. The images have with 8 bits per channel (r, g, b). Each pixel of the image is represented by a set of three 8 bit values from 0 - 255 corresponding to each channel. Any pixel at co-ordinates {i, j} in the image is represented as

$P(i, j) = \{r_{ij8}, g_{ij8}, b_{ij8}\}$; $r_{ij8}, g_{ij8}, b_{ij8}$ each can have any value between 0 – 255 and each value is 8 bits long

3.1 Description of the Stages of Preprocessing

Once the three channel (r,g,b) image is obtained, some initial processing is necessary to correct any shade irregularities in the image, which is the result of the scanning procedure used. A shade correction algorithm is applied which compensates for any non-linearities in the intensity of the image [SAW77], making it a good rendition of the original board. This image is now used to generate the necessary histograms that will be used in the clustering process. The steps involved in generating the histograms will be described in the following sections.

3.1.1 Generation of the Histogram

The first step in generating a histogram of an image is to perform background extraction on the image i.e., locate the actual edges of the board in the image. The histogram of the image is computed after the background pixels have been eliminated. It is important that the algorithms used for background extraction work fairly well, or else the background pixels could be mistaken for another cluster in the segmentation algorithm

To facilitate the process of background extraction, all the images are scanned against a blue background. Clearwood generally has relatively low quantities of blue and it is easy to separate the background from the image. The algorithm first detects the left and right edges of the board in each line of the image. In each line of the image if a left edge pixel L(i, j) (i, j are the coordinates of the pixel in the image) and a right edge pixel R(i, j) exists then the histogram is computed between the two edges. Let P_b(i, j) be any pixel between left edge L(i, j) and right edge R(i, j) with a value $\{r_{ij8}, g_{ij8}, b_{ij8}\}$. Once the edges are detected, without much loss of color resolution the last two bits for each channel is discarded, giving six bit values for each channel represented as $\{ r_{ij}, g_{ij}, b_{ij}\}$ [CON85]; thus each pixel in the image can also be represented by the 6 bit values $P_b(i, j) = \{r_{ij}, g_{ij}, b_{ij}\}$, where each of r_{ij}, g_{ij}, b_{ij}, can have values from 0 - 63. The 3 dimensional full color histogram H(i, j, k) is computed by incrementing $H(r_{ij}, g_{ij}, b_{ij})$ for every pixel P_b(i, j)

$$H(r_{ij}, g_{ij}, b_{ij}) = H(r_{ij}, g_{ij}, b_{ij}) + 1$$

over all P_b(i, j), where i,j are the coordinates of a pixel in the image. Since each of r_{ij}, g_{ij}, b_{ij} can vary between 0 - 63 the size of the histogram is 64x64x64 = 262144.

The algorithm used for detecting the left edges of the board is as follows:

1. Start from the left edge of the board, ($j = 0$)
2. Examine each pixel $P(i, j)$ while j < width of the image.
3. If $(b_{ij8} > 200)$ or $(b_{ij8} - r_{ij8})$ > threshold, (still in the background region) increment j and go to step 2. The threshold is generally set to 10.
4. Else mark $P(i,j)$ as $L(i, j)$ for that line and move to the next line, start from step one.

To detect the right edge for a line, a similar procedure is followed except, that j = width of the image initially, and is decremented after each pixel is examined.

Figure 3.1(a) and (b) show the image of a board and the corresponding edges which were detected. Figure 3.1(c) shows a portion of the board with the edge marked on it where it seems like the edges are at times detected 2-3 pixels towards the interior of the board rather than the exact edge pixel. But if that section is enlarged it was found that the edge is not clearly defined by just one pixel, and there is a gradual change from the background color to the board. In such a case it is better to detect the edge at the location where the transition ends rather than where the transition starts. For this, the boundary conditions have to be made very tight, which is achieved in step 3 of the edge detection algorithm. If a trade-off is to be made, it is better to leave out a few of the edge pixels than include the background pixels. Otherwise, the transition regions could appear like a different cluster and complicate the segmentation process. There are, however, situations where a small amount of background pixels do come in the histogram. This happens if a piece of splinter is standing out of or if the board has a hole in it. But the number of pixels included in this manner are negligible and do not affect the clustering process.

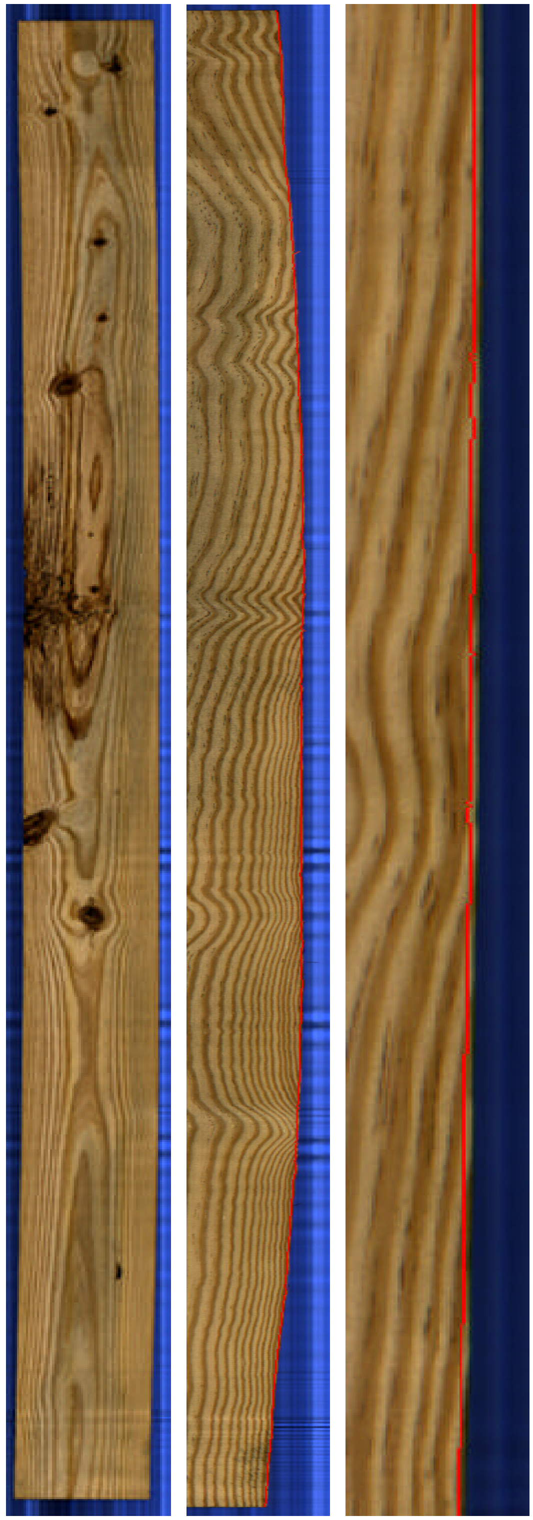

Figure 3.1: (a) Image of a pine board p7a.dat, (b) Right edge that was detected, (c) Detailed view of the edge

3.1.2 Generation of 2-Dimensional Histograms

Instead of using all the three channels (red, green and blue) to segment the image, the effects of using only two channels were also studied. The amount of information present in each channel varies across species, and it is at times possible to ignore one of the channels of information and still obtain good segmentation results. For instance, in red oak boards, it was found that using only the red and blue channels provided the same results as using all the three channels. This is a very useful feature, since the data size is reduced from 262144 to 4096, which reduces the processing time. Further, it is convenient to visualize a 2 dimensional histogram and examine the features as against a 3 dimensional histogram.

Two dimensional histograms can be generated by considering only two channels of information instead of all the three (r, g, b). The histograms can be of the red and blue channels, red and green or green and blue. The histogram using only the red and blue channels is represented as r-b histogram etc.

If a pixel $P_b(i, j)$ has values $\{r_{ij}, g_{ij}, b_{ij}\}$, where each of r_{ij}, g_{ij}, b_{ij} are 6 bit values ranging from 0 - 63, the r-b histogram is incremented as,

$$H(r_{ij}, b_{ij}) = H(r_{ij}, b_{ij}) + 1$$

Similarly the 2 dimensional histograms are computed for other pairs of channels namely r-g and b-g. The histograms thus obtained are now ready for further processing i.e., clustering to obtain the segmented image.

3.2 Clustering a Histogram to Obtain a Map

This section describes the general steps used to obtain the segmented image by clustering the multi-dimensional histogram of the image. The clustering process is performed on the histogram and it divides the histogram into various groups or classes, which ultimately correspond to different regions on the board surface. The classes define a particular pixel on the board as a part of a defect or clear-wood. If a 3 dimensional full color histogram is used, at the end of the clustering process, a map M_3(i, j, k) is generated, where i, j, k vary from 0 - 63. If $M_3(i, j, k)$ = c1, c1 is the class or group to which the color r_i, g_j, b_k, belongs to. Every pixel in the image belonging to the board is mapped based on M_3. The board is defined by locating the edges as mentioned in Section 3.1. If pixel P_b(i, j) = {r_{ij}, g_{ij}, b_{ij}}, (ignoring the last two bits, and using only 6 bits of information), it belongs to the region defined by $M_3(r_{ij}, g_{ij}, b_{ij})$.

Similarly in two dimensions, if the red and blue channels are used, a map $M_2(i, j)$, is generated, where i, j vary from 0 - 63. $P_b(i, j)$ belongs to the region defined by $M_2(r_{ij}, b_{ij})$. Likewise a similar map is obtained using the other two 2 dimensional histograms for the clustering process.

3.3 Obtaining the Segmented Image

The original image is mapped using the map M_3 (if 3 dimensional clustering has been done) to obtain the segmented image. In future the map will be referred to as M where it can be M_2 or M_3 depending on the dimension in which the clustering is performed. Each pixel of the original image $P(i, j)$ consists of an ordered triplet {r_{ij}, g_{ij}, b_{ij}} at location {i, j}. The segmented image $S(i, j)$ is obtained using

$$S(i, j) = M_3(r_{ij}, g_{ij}, b_{ij})$$

If M is a 2 dimensional map M_2 obtained using 2 channels, only those channels of the original image are used to look up the value in the color map, for example, if only the red and blue channels are used, $S(i, j) = M_2(r_{ij}, b_{ij})$. If the red and green channels are used then $S(i, j) = M_2(r_{ij}, g_{ij})$ etc.

3.4 General Steps Followed to Segment an Image Using Clustering Techniques on the Histogram

The general steps followed to obtain a segmented image from the original image that were described in the previous sections, are summarized below. These steps are common to all the clustering algorithms described in this thesis.

1. Perform background extraction
2. Create a 6 bit r, g, b histogram form the original image. Create two dimensional histograms if necessary
3. Perform clustering on the histograms to obtain a map M (M_2 or M_3 depending on whether 2 or 3 channels were used)
4. Map the original image using M_2 or M_3 to obtain the final segmented image.

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3.5 Brief Note on the Boards Used for Testing

Three different species of wood were used for testing purposes. The boards were picked so as to include most of the defects commonly found in those species. Further color based defects like blue stains were also included since these are hard to detect using black and white segmentation. The test boards consisted of a set of eight pine boards, five yellow poplar boards and over thirty oak boards. A brief description on their characteristic features and uses are given below.

3.5.1 Southern Yellow Pine

Southern yellow pine is a mixture of four different species that are very hard to distinguish by looking at the wood. It is commonly used in structural applications. The sapwood is a yellowish white and the heartwood is a reddish brown. The sapwood is usually wide in second-growth strands (most of the wood comes from this region). Growth rings are readily seen in these species with a sharp contrast between last year's latewood (darker) and next year's earlywood (lighter).

3.5.2 Red Oak

Red oak is a mixture of many species. It is used largely in household furniture/fixtures. The sapwood is nearly white and the heartwood is brown with a tinge of red. The open pores and broad conspicuous rays of red oak add to its preferred use in household furniture and cabinets. The growth rings are well defined in red oak but there is small color variation across a growth ring

3.5.3 Yellow Poplar

Yellow poplar consists of one species. It is used in pallets and household furniture/fixtures. The sapwood is white and frequently several inches thick. The heartwood is yellowish brown, sometimes streaked with purple, green, black, blue or red. The wood is light grained with subtle color variations.

3.5.4 Description of Some of the Most Commonly Found Features and their Significance

There are a wide number of defects which are found on the surface of the boards [NHLA94]. Some of these features like decay, spike knots, unsound knots etc. affect the strength of the wood, and are termed as structural defects. Other defects like color variation, stains, sound knots, pith etc., affect the grade of the board but do not weaken the structure of the material. In such a case they can be used as *paint grade* material, and the defects can be concealed with the use of paints and dyes. Whereas if structural defects are present, they cannot be used even as paint grade material and the defects have to be eliminated. Color variations on the board do not technically affect the grade of the lumber, but fine furniture and similar applications generally require a uniform color. It is thus important to extract these features from the board, if the application so warrants. The segmentation procedure will have to be such that it can adapt itself to the needs of the application. For instance, if the boards are needed in applications using paint grade material or lower quality furniture, only a few defects need to be segmented out. This makes the task of the recognition software much simpler, and faster. If the boards are to be lightly stained, there would be another set of features which are permissible. For instance all defects might have to be segmented out except color variations. Finally, if the boards are needed for fine furniture, all the defects (features) might have to be segmented out. In case non-structural defects are present, the boards can be suitably sorted and used in other applications so as to maximize the utilization.

Color variations are a common feature of the heartwood of yellow poplar. Pine and oak do not exhibit any significant color variation between the heartwood and sapwood. It is also common to have a wide range of colors in the heartwood of yellow poplar, which could adversely affect the quality of the final product depending on the application. Pine generally has a sharp contrast between the earlywood and latewood regions, with the latewood being much darker. The color of the knots are sometimes very close to the color of the latewood, which complicates the segmentation process.